BENTON HARBOR POWER PLANT LIMNOLOGICAL STUDIES

PART XIV. WINTER OPERATIONS 1972-1973

John C. Ayers
William L. Yocum
Erwin Seibel

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PREVIOUS PARTS OF THE REPORT SERIES RELATIVE TO THE
DONALD C. COOK NUCLEAR STATION

Benton Harbor Power Plant Limnological Studies

Part I. General Studies. J. C. Ayers and J. C. K. Huang. April 1967. 31 p.

Part II. Studies of Local Winds and Alongshore Currents. J. C. Ayers, A. E. Strong, C. F. Powers, and R. Rossmann. December 1967. 45 p.

Part III. Some Effects of Power Plant Waste Heat on the Ecology of Lake Michigan. J. R. Krezoski. June 1969. 78 p.

Part IV. Cook Plant Preoperational Studies 1969. J. C. Ayers, R. F. Anderson, N. W. O'Hara, G. Kidd. March 1970. 92 p.

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Part XI. Winter Operations 1971-1972. J. C. Ayers, W. L. Yocum. September 1972. 26 p.

Part XII. Studies of the Fish Population Near the Donald C. Cook Nuclear Power Plant, 1972. D. J. Jude, T. W. Bottrell, J. A. Dorr III, T. J. Miller. March 1973. 115 p.

Part XIII. Cook Plant Preoperational Studies 1972. J. C. Ayers and E. Seibel. March 1973. 281 p.

INTRODUCTION

In Part VI (March 1971) of our report series relative to the Donald C. Cook Nuclear Station, we established the following report format:

A. COOK PLANT PREOPERATIONAL STUDIES

- A.1 Recording of Local Water Temperatures
- A.2 Study of Floating Algae and Bacteria
- A.3 Development of a Monitor for Phytoplankton (ABANDONED)
- A.4 Study of Attached Algae
- A.5 Study of Zooplankton
- A.6 Study of Aquatic Macrophytes
- A.7 Study of Benthic Organisms
- A.8 Study of the Local Fishes
- A.9 Support of Aerial Scanning
- A.10 Study of Entrainment and Impingement

B. SURVEYS OF EXISTING WARM WATER PLUMES

C. THE ICE BARRIER AT THE COOK PLANT SITE

D. EFFECTS OF EXISTING THERMAL DISCHARGES ON LOCAL ICE BARRIERS

E. EFFECTS OF RADIOACTIVE WASTES IN THE AWUATIC ENVIRONMENT

- E.1 Gamma Scan of Bottom Sediments (FINISHED)
- E.2 The Most Sensitive Organism for Concentration of Radwastes (FINISHED)
- E.3 Study of Lake Michigan's Present Radioactivity Content (FINISHED)

This report covers only sections C and D of the above format; the rest were brought up-to-date in Part XIII.

ACKNOWLEDGEMENTS

We gratefully acknowledge general assistance received from Mr. Jon Barnes of Indiana and Michigan Power Company and from Ames/Warnock, commercial photographers from Benton Harbor. Other persons who assisted with parts of the work are acknowledged in the text.

Photographs not otherwise accredited were taken by W. L. Yocum.

C. THE ICE BARRIER AT THE COOK PLANT SITE

Erosion at the Cook Plant Cottage

Though no one doubts that the Lake Michigan shoreline has suffered shore erosion during the present period of high lake level, it may be of interest to have on the record some of the conditions that used to be present at and near the Cook Plant cottage. Our first real contact with the Cook cottage was on 11 May 1967 when a current meter was set between the inner and outer sand bars and an anemometer and wind vane were installed in front of the cottage. The results of that study are reported in Part II of our report series.

On that day H. K. Soo of our staff was trying out a new half-frame camera designed for an offshore meteorological tower near Muskegon, Michigan. Thanks to Mr. Soo, we have a few pictures from 11 May 1967 that can serve as background against which to evaluate the present eroded conditions near the Cook cottage.

On 11 May 1967 there was in front of the cottage a broad beach about 150 ft in breadth which ended inshore at a beach berm about 3 ft high and which, with a substantial growth of dune grass, extended inshore about 50 ft to the base of the sand dune bluff.

Figure 1 shows the grassy beach berm and the anemometer and wind vane staff which were to be erected at the site. The staff was erected at the outer edge of the beach berm (out of the picture to the left). The sand dune bluff began to ascend to the right of the tree in the right of the photo. Figure 2 is a view down from the cottage showing the anemometer and wind vane staff as a vertical line behind tree limbs just to the right of lower center. The outer edge of the beach berm shows between the rocks

in the foreground. The wide beach is also visible. Figure 3 shows the carrying of the cable from the current meter, anemometer, and wind vane up the face of the dune bluff to be connected to an operations recorder in the cottage. The vegetated nature and low angle of repose of the dune bluff are shown, along with an old set of stairs to the beach.

Figure 4 is of the bluff face, from the point where Figure 3 was taken, on 1 February 1973. The beach, the beach berm, and the face of the bluff including the two lower parts of the old stairs have been carried away. Figure 5 is a view northward along the shore in front of the cottage. The two clumps of shrubs, which have slid down the bluff face, were parts of the plantings in front of the cottage.

The Ice Season of 1972-1973

In this section we employ the same terminology for parts of the shore ice complex, as has been used in previous reports of our winter operations. This terminology is illustrated in Plate 1.

The ice season of 1972-1973 was different from seasons observed previously in two major respects: 1) a pronounced January thaw existed from mid-January until late January, and 2) the lake was in a very high water level condition and severe shore erosion had preceded the formation of ice. The January thaw destroyed the first ice formed, and the rest of the winter was occupied by reformations and meltoffs of comparatively minor shore ice complexes. Shore erosion, putting large amounts of sand into suspension and apparently also uncovering darker sand, resulted in much more and much darker sand being incorporated in the ice on and immediately along the beach. This was different from conditions in previous winters observed.

The pre-ice condition was that of the frozen beach (Figs. 6 and 7).

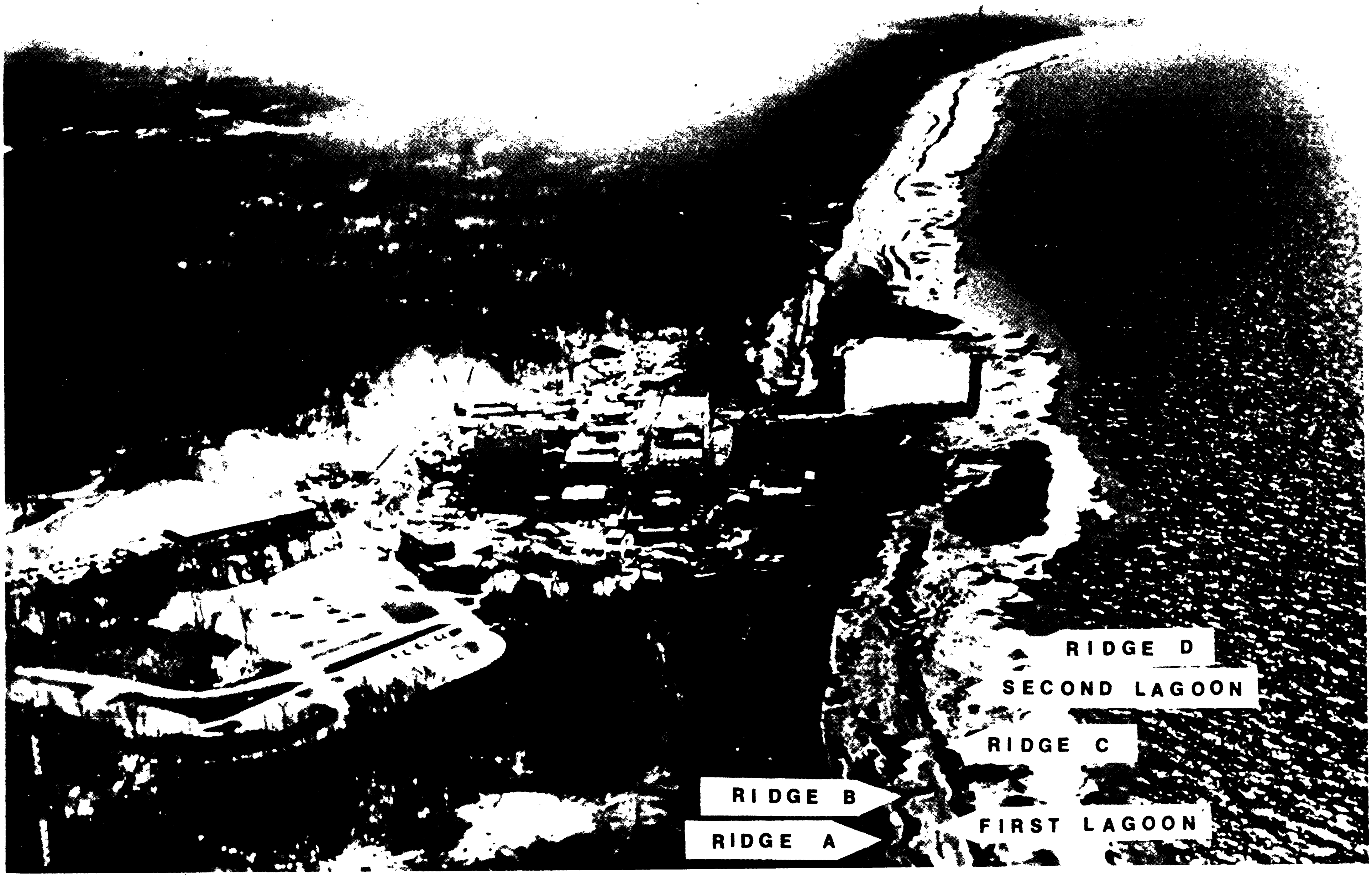

Plate 1. Illustration of the terms used in discussion of shore ice structure. Photo by N. W. O'Hara. 17 March 1971.

Figure 7 shows in lower right some wave-tossed blocks of frozen sand, which also show in Figure 20.

The first formation of ice was on 16 December, and by 17 December a good ice ridge was present (Jon Barnes' ice log). Conditions during our first foot survey on 20 December are shown in Figures 8 through 14. Figure 8 looks westward from the beach north of the plant and shows the very dark, very sandy ice and iceballs on the beach and smaller iceballs and decreasing sand color toward the lake. A pair of flat dark slabs of frozen sand show in lower left. It appears that the wave action accompanying the first ice formation threw these ashore from the edge of the frozen beach. The very dark ice and iceballs on the beach in the foreground apparently drew their sediment loads from the same stratum that the slabs came from. Figure 9 looks north along the north beach and shows the extreme size and darkness of the iceballs on the beach. Figure 10 shows at left the smaller iceballs on the first lagoon and ridge C developing in the background. Figures 11 and 12 are views northward and southward, respectively, along the face of ridge C; large lumps of the very dark sandy ice are present in both views. Figure 13 is of the field of sandy, but less dark, pancake ice lakeward of the ridge face. The hole, on the landward side of the access road to the north beach (the elevated surface in upper left), from which one of the ENDECO recording current meters was recovered, is shown in Figure 14. The meter had been torn from its mooring several hundred feet out in the lake and thrown ashore.

Figures 15 and 16 are the beaches north and south of the plant on 27 December. In both, the dark initial ice has darkened further by lag concentration of sand under sun action. A road has been cut through the beach

ice on the north beach. In both, ridge C is being augmented with new white ice.

On 6 January the conditions north of the plant (Fig. 17) and south of the plant (Fig. 18) were different from those of 27 December only in that on the latter date the ice was covered by a thin layer of snow and that the face of ridge C contained normally-sandy-colored ice.

On 11 January (Fig. 19) the view northwestward along the north beach showed a fully developed shore ice structure. Remains of the road, cut through the dark beach ice, can be seen in the foreground. Ridge C with extinct blowholes reaches into the distance from middle left side; beyond it and above left center is the frozen second lagoon; and in left three quarters distance ridge D shows in shadowed outline in front of an ice field reaching to the horizon. Figure 20, southward from the south beach, shows the same ice conditions. Between 6 and 11 January there had been a very extensive growth of the ice complex, but there were no intervening observations to show how, or how fast, the increase took place. It was to fill such gaps that the Camera Monitor was needed and developed.

Figures 21 through 26 present the ice conditions during our foot survey of 12 January. Figure 21 presents an overall view of ice conditions, as seen from the top of a sand dune near the south side of the plant site. The very dark initial ice lies on the beach behind the sign in the foreground. A man stands on the frozen first lagoon; foreshortened behind him is the C ridge with extinct blowholes; the rough second lagoon extends from the C ridge to the D ridge (shown in part as a dark line in right three quarters distance); and beyond the D ridge an extensive ice field reaches to open water on the far horizon. Figure 22 shows the initial dark ice on the beach north of the

plant. In center foreground a large sun-rotten dark iceball of the initial ice is shown with a man's glove on top for scale. In Figure 23 the view is somewhat west of north along the north beach. Sun-rotted iceballs of the initial ice are in the right middle distance; from lower left to center is the bare ice of the first lagoon; beyond center it is covered by ice thrown over the C ridge; the C ridge with blowholes essentially occupies the skyline in this picture. Figure 24 is of the face of ridge C north of the plant and looks nearly northwestward; the sandy ice of the ridge is at right (the large blocks near right center will be visible in pictures on several later dates); the whiter ice with greyish pieces of sheet ice which occupies most of the rest of the picture is the frozen second lagoon; and in the center three quarters distance elevated portions of the D ridge show as shadow outlines against a belt of sunlight in the far distance. In Figure 25 the foreground is of the ice making up the second lagoon west of the north beach. Large pieces of pancake ice and small iceballs on the surface have apparently all been overlaid by small pieces of broken clear sheet ice which act like mirrors; in four fifths distance are two low mounds of ridge D; and beyond is an extensive ice field reaching to the horizon. Figure 26 is from the top of ridge D and looks lakeward over the semifrozen ice field outside the ridge. Large cakes of sheet ice and some large pieces of pancake ice, as well as the intervening slush, are covered with small broken pieces of sheet ice which reflect light.

Apparently the fully developed ice complex which had been present on 12 January remained unchanged, for on 16 January Plant Manager Robert W. Jurgensen began a series of multihourly monitoring photographs, and his photograph of 1135 is used as Figure 27. The prominent ice blocks on the face of

ridge C, which were mentioned in the discussion of Figure 24, show just below middle center and ridge D shows as an incomplete dark line just above middle center. The height of Mr. Jurgensen's window and its distance farther south from the point where Figure 24 was taken, have produced foreshortening and diminution of features in this figure.

Figure 28, taken at 1200 on 17 January, shows the beginning of meltoff of the fully developed complex of shore and lake ice that had been present from 11 January (Figure 19) and possibly longer, but not from so far back as 6 January (Figure 17). In this picture there are, from right to left from the shoreline: the very dark brown remnants of the initial ice; one or two pools of melt water in the first lagoon; sandy ridge C with its prominent ice blocks in middle center, receiving on its face white ice fragments from the melting second lagoon; the melting second lagoon with floating ice pieces; ridge D showing as a thin sandy line extending to left and right from above middle center; melting in the offshore ice field; and open water on the horizon. Figures 29, 30, and 31 show further stages of this meltoff on 18 January. Figures 32 and 33 are of the melt stages on 19 January.

On 19 January we made a short visit to the beach in front of the plant. Figure 34 shows blowhole activity and some augmentation of ridge C with sandy new slush ice. Figure 35 shows the heavy lag concentrate of very dark brown sand on the surface of the initial ice remaining on the beach.

Figures 36, 37, and 38 show the progression of the melting on 22, 23, and 24 January. By 24 January the meltoff was nearly complete, there being left only remnant ice blocks most of which had been pushed onto the beach.

On the night of 24-25 January there was renewed formation of the icefoot

with white slush ice as the building material (Fig. 39 shows the north beach, Fig. 40 the south beach). The new ice underwent rapid melting (Fig. 41 on 26 January and Fig. 42 on 27 January) and was destroyed by a storm on 28 January (Fig. 43). The north beach remained iceless on 29 January (Fig. 44).

On 30 January new white slush ice had been deposited and the process of icefoot formation had begun again (Fig. 45). During 31 January the new ice underwent melting (Fig. 46). Figure 47 shows remnants of the ice pushed up onto the beach; this was early in the day on 1 February. Figure 48 on the same day shows a cavity beneath one of the blocks pushed ashore. We at present believe that this sort of undercavity formation (how it comes about is not known) destroys the "grip" of the ice on the bottom and that buoyant force and wave action then combine to push the ice blocks ashore. Figure 49 shows the north beach devoid of ice later in the day on 1 February. The heavier ice along the beach immediately south of the plant had not melted on 1 February (Fig. 50).

On 2 February the north beach was devoid of ice, but a sand ridge lay in the water's edge and retained shoreward of it a belt of water suggestive of a residuum of the first lagoon (Fig. 51). Figure 52 on 3 February shows a normal beach; wave action had destroyed the sand ridge and belt of water present on the 2nd. The photos from the Camera Monitor show that the beach stayed in this condition until 9 February.

Figure 53, on 9 February, shows the frozen beach and the bare beginnings of a slush ice icefoot. Figure 54 is of the new slush ice icefoot on the north beach on 10 February. Figure 55 shows the south beach with its new icefoot of slush ice on 10 February. Figure 56 is of the north beach on

11 February and shows melting of the new icefoot. On 12 February the continued melting of the recent icefoot is shown in Figure 57. Continued melting of the icefoot during 13 February (Fig. 58) and 14 February (Fig. 59) were during quiet weather, but a storm (Fig. 60) destroyed all remaining ice early on 15 February. Figure 61 is of the south beach, iceless under storm conditions early on 15 February.

Later in the day, 15 February produced an influx of water-borne slush with accompanying development of a white slush ice icefoot (Fig. 62). The Camera Monitor showed that this condition of the ice was maintained until 20 February.

On 20 February new and somewhat more sandy slush ice arrived at the face of the icefoot (Fig. 63). During 21 February the arrival of sandy slush ice continued (Fig. 64). By 22 February an offshore ice field had arrived, compacted, and elevated the sandy slush ice arriving during the preceding two days until it was a distinct belt amongst the surrounding white slush ice (Fig. 65). On 22 February we visited the site on foot. Figure 66 is a view northward along the north beach. Again, there is a collection of large and very dark sandy iceballs on shore, with fewer and smaller ones on the surface of the first lagoon at left center. Ridge C, elevated and sandy, shows in the background. The compressed and elevated sandy slush ice composing ridge C is shown in a view southward from a little north of the plant (Fig. 67). This condition continued through 23 February.

Figure 68, on 24 February, shows the next step in the progression (compare to Fig. 65). Offshore melting was in progress and floating ice pieces were accumulating against the face of sandy ridge C, which runs from near lower left to right three quarters distance. Figure 69, on 25 February, is

of the north beach with the sandy ice, compressed into ridge C, with a lakeward augmentation of white ice pieces on its face. The offshore ice field has completely vanished. The ice remained in this condition until 1 March. Figure 70, looking northward (and on foot) from in front of the plant on 26 February, does not show the sandy ice incorporated into ridge C, though ridge C shows as the irregular and elevated ice surface fronting the open lake water. Figure 71, looking southwestward along the south beach, shows the same conditions. Figure 72, on 27 February, is from one of our overflights of the Cook Plant area. The shore icefoot, first lagoon, sandy (darker) ridge C, and a collection of trash ice cakes against the face of ridge C are visible.

Figures 73 through 80 present the day-by-day progress of the final meltoff from 1 March to 8 March.

Photographic Monitoring

During the winter of 1971-1972 we realized that photographs of ice conditions at weekly or biweekly intervals were insufficient to reveal the speed or slowness with which changes in ice condition were taking place or the dates when changes occurred. It was therefore decided to augment the photographic coverage of Ames-Warnock with time-lapse photography on a daily or less than daily schedule.

A time-lapse camera was procurred and mounted in a north-facing window of the plant office building.

The time-lapse camera unit consists of a commercially available camera and accessories coupled to a special timer designed and constructed by H. K. Soo and Bruce Higgins of our staff.

The camera is a Canon F-1 single lens reflex 35 mm camera equipped with

a Canon 50 mm f1.4 lens, a Canon EE Servo finder which provides automatic exposure control, and with a Canon motor drive which advances the film and cocks the shutter after each exposure.

The special timer controls the frequency of exposures. Two electrical timers, one running on a 24-hour cycle, the other on a 2-hour cycle, control relays that trigger the camera every two hours during a selected 8-hour period between sunrise and sunset.

During its trial period, the timer broke down and the camera and timer were removed for repairs. Plant Manager Robert Jurgensen covered our breakdown period with his own equipment and photographs from his office window. Except for weekends he photographed ice conditions at multihourly intervals. His pictures were excellent and our thanks are extended to him.

Two of his pictures (Fig. 31 and 37) on 18 and 23 January covered a period of meltoff and proved to be superimposable in a study of the relative positions of the two outer ice ridges (ridges C and D) and the two sand bars along shore. The slides were projected in an enlarger and the positions of ice ridges and sand bars (as shown by lines of breaking waves) were traced or sketched. An anemometer pole and posts of the plant's fence provided reference points for registration. They and the positions of the ice ridges and of the lines of breaking waves are indicated in Plate 2.

The plate shows that after the meltoff waves were breaking in rows at the positions that the ice ridges had occupied. This is taken as evidence that the ice ridges develop over the sand bars.

The time-lapse camera was returned to service on 24 January and operated on a four-photos-during-daylight-hours basis until it was stopped on 16 March, well after the final meltoff was complete.

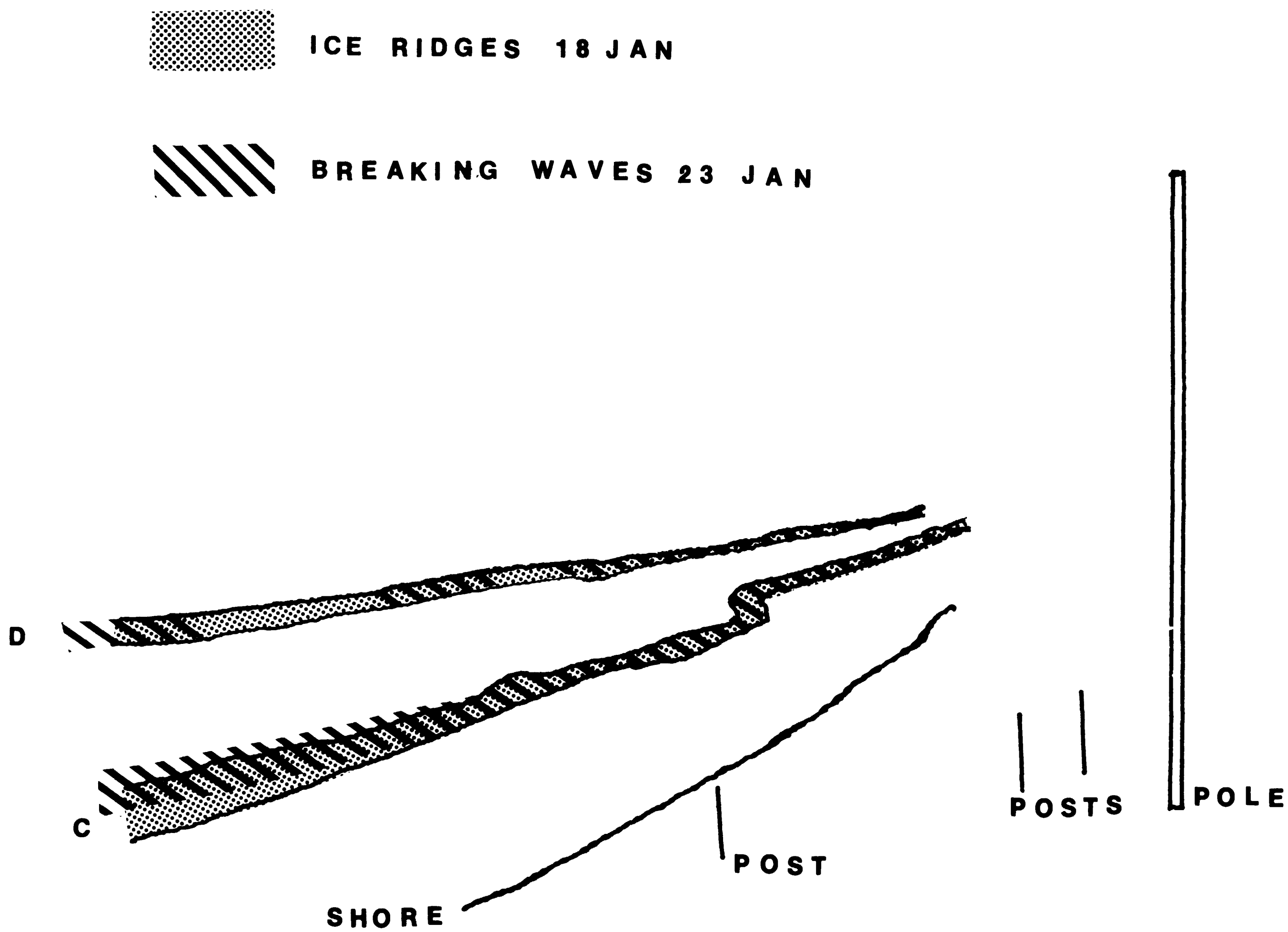

Plate 2. Superposition of the positions of the C and D ice ridges on 18 January and rows of breaking waves on 23 January. Photos by R. W. Jurgensen.

The time-lapse camera (also designated Camera Monitor) showed details of ice behavior and provided means of documenting and dating events hitherto not available. As examples, note the pushing of ice onto the beach during meltoff (Figs. 46 through 49) and the sudden formation of new ice (Fig. 60 versus Fig. 62 both on 15 February).

It is anticipated that the Camera Monitor will be a valuable adjunct to next winter's ice studies.

Our thanks are tendered to the following members of the Cook Plant Operations Technical Deparment for supervising the operation of the time-lapse camera: Thomas Pinkham, Mark Schwan, Preston Helms, William Hullinger, Donald McAlhany, James McDowell, Curtis Niles, Douglas Nister, James Pounders, and Gregory Swan.

Ice-sediment Relationship

To get a perspective on the relationship between the role of ice and its sediment-carrying ability, 8 ice samples were collected on the field trip of 11 and 12 January. The samples were collected near the Cook Plant, near Palisades and near the Chalet on the Lake north of the Cook Plant. For sediment size determination and because of difficulty separating the sediment from the ice, the original ice-sediment samples were randomly lumped into two for sediment analysis. Only qualitative information is therefore possible. The following table gives the data for the two samples.

	SAMPLE 1			SAMPLE 2		
DIAM (mm)	WEIGHT (g)	% TOT	CUM %	WEIGHT (g)	% TOT	CUM %
4.0	0.05	0.02	0.02	8.45	2.28	2.28
2.38	0.45	0.19	0.21	1.70	0.46	2.74
2.00	0.20	0.08	0.29	0.60	0.16	2.90
1.68	0.10	0.04	0.33	0.65	0.18	3.08
1.41	0.50	0.21	0.54	0.90	0.24	3.32
1.00	1.40	0.58	1.12	2.90	0.78	4.10
0.50	6.50	2.70	3.83	14.90	4.02	8.12
0.125	230.10	95.74	99.56	337.90	91.21	99.33
0.062	0.95	0.40	99.96	2.10	0.57	99.90
PAN	0.10	0.04	100.00	0.35	0.09	99.99
TOTAL	240.35			370.45		
Ice Wt	7725			7725		
% SED	3.11			4.80		

The predominant size is fine sand making up over 90% of the total sediment. Most of 0.062 mm size range was found to be magnetite. In general this qualitative analysis revealed a fairly well sorted sediment being carried by the ice.

Plans are that ice cores will be taken this fall to ascertain where in the ice most of the sediment is located and to establish more clearly the role of ice in the movement of sediment in the nearshore zone.

FIGURE CAPTIONS

Fig. 1 Installation of anemometer on beach berm in front of the Cook cottage. The face of the bluff began behind the tree on the right. 11 May 1967.

Fig. 2 View down from the cottage. The outer edge of the grassy beach berm shows between the stones in the foreground. 11 May 1967.

Fig. 3 The face of the bluff taken from the beach berm. The vegetated nature and rather low angle of repose of the bluff is shown. 11 May 1967.

Fig. 4 The face of the bluff in the same position as Figure 3. 1 February 1973.

Fig. 5 Eroded face of the bluff in front of the cottage. Clumps of vegetation from in front of the cottage are in various stages of sliding down the slumping dune face. 1 February 1973.

Fig. 6 View along the beach north of the plant. Snow covered frozen beach; no icefoot. 7 December 1972. Photo by Ames-Warnock (A-W).

Fig. 7 The snow covered frozen beach south of the plant. The snow covered blocks back from the water's edge in lower right are blocks of frozen sand (see the same view on 11 January). 7 December 1972. Photo by A-W.

Fig. 8 View lakeward from the north beach showing the extremely sandy nature of the winter's first shore ice. Great numbers of ice-balls lie on the surface, including some near the beach that are extremely large and extremely sandy. Two slabs of frozen sand lie on the beach landward of the ice edge in lower left. 20 December 1972.

Fig. 9 Exceptionally large iceballs heavily loaded with sand. 20 December 1972.

Fig. 10 General view of the ice surface. Ice on the shore shows black in the background at the right; ridge C is in the background at left. 20 December 1972.

Fig. 11 The face of ridge C, looking northward from north of the Cook Plant. Large blocks of very sandy ice on the ridge and large field of pancake ice lakeward of the ridge. 20 December 1972.

Fig. 12 The face of ridge C, looking southward from north of the Cook Plant. 20 December 1972.

Fig. 13 Sandy pancake ice of the field outside ridge C. Note also the sandy color of the new spray ice in the right foreground. 20 December 1972.

Fig. 14 Upper left: the elevated surface is the semi-stabilized access road to the north beach. The lake is out of the picture to the left. The hole in the center is where one of the ENDECO recording current meters was recovered after the ice had formed. It had been torn from its mooring on the lake bottom several hundred feet offshore. 20 December 1972.

Fig. 15 The ice along the beach north of the plant. The original sandy ice has become more heavily sand laden by lag concentration. A road has been cut through the A and B shore ridges. Large iceballs in the foreground. The C ridge is receiving augmentation of new ice. The frozen and sandy first lagoon lies between the C ridge and the road. 27 December 1972. Photo by A-W.

Fig. 16 Ice south of the plant. Blocks of frozen sand, iceballs and a heavy lag concentrate covering of sand on the beach. The frozen first lagoon carrys a less dense cover of sandy iceballs. Augmentation of the C ridge with fresh ice. 27 December 1972. Photo by A-W.

Fig. 17 Ice along the beach north of the plant. Developing blowholes on the C ridge. 6 January 1973.

Fig. 18 Along the beach south of the plant, showing the shore ridge, the frozen first lagoon, and the C ridge with developing sand-tinted blowholes. 6 January 1973.

Fig. 19 Along the north beach. Remains of the road in the ice on the beach. Ridge C has been heavily augmented. The frozen second lagoon, ridge D, and a large ice field show at left. 11 January 1973. Photo by A-W.

Fig. 20 The south beach with blocks of frozen sand in right foreground. Ridges A and B and the first lagoon are nearly covered with drifted snow. Extinct blowholes of ridge C show in the middle distance with the second lagoon, ridge D, and the ice field successively in the distance beyond them. 11 January 1973. Photo by A-W.

Fig. 21 Overview of ice conditions, from a dune south of the plant. The very dark ice of the shore shows behind the sign in the foreground; the man is standing in the first lagoon, ridge C with three extinct blowholes is behind the man; the rough frozen second lagoon reaches from ridge C to ridge D in the three quarter distance; an extensive ice field reaches to the horizon beyond ridge D. 12 January 1973.

Fig. 22 Sun-rotted large very sandy ice of the initial ice formation. Glove for scale. 12 January 1973.

Fig. 23 North of the plant. Sun-rotted iceballs of the initial ice at right; near center is bare ice of the first lagoon; and at left ridge C. 12 January 1973.

Fig. 24 The face of ridge C and the second lagoon; high portions of ridge D show against the band of sunlight in the distance. North of the plant. 12 January 1973.

Fig. 25 Large cakes of pancake ice in the second lagoon. Sun glints are small pieces of sheet ice. A low portion of ridge D in the background. 12 January 1973.

Fig. 26 From ridge D looking lakeward over the ice field. Pancake ice and slabs of sheet ice. 12 January 1973.

Fig. 27 View along the north beach, showing a fully developed shore ice complex and an extensive ice field reaching to the horizon. 1135 16 January 1973. Photo by Robert W. Jurgensen (RWJ).

Fig. 28 The north beach shore ice complex, with melting begun in the offshore ice field and in the second lagoon. 1200 17 January 1973. Photo RWJ.

Fig. 29 Following melting begun on 17 January in a fully developed ice structure, this view shows melting in the offshore ice field, ridge D as a sandy line in center middle distance, the partially melted second lagoon, and sandy ridge C with sandy first lagoon and very sandy shore ridges. Trash ice from the melting second lagoon is impacting on the face of ridge C as a band of white ice. 0920 18 January 1973. Photo by RWJ.

Fig. 30 Continued melting, and the formation of a breach through ridge D. 1330 18 January 1973. Photo by RWJ.

Fig. 31 Breach in ridge D reaches nearly to the left side of the picture. 1730 18 January 1973. Photo by RWJ.

Fig. 32 Ridge D completely destroyed, its remnants pushed against the face of sandy ridge C. Substantially increased melting in the first lagoon. 1205 19 January 1973. Photo by RWJ.

Fig. 33 Further augmentation of ridge C by ridge D remnants. First lagoon is a nearly continuous band of water. 1625 19 January 1973. Photo by RWJ.

Fig. 34 Blowhole activity in front of the plant. 19 January 1973.

Fig. 35 Heavy lag concentrate of sand on the surface of the initial ice. Hat for scale. 19 January 1973.

Fig. 36 Condition of the north beach ice. 22 January 1973. Photo by RWJ.

Fig. 37 Ice along the north beach broken up and pushed ashore. 23 January 1973. Photo by RWJ.

Fig. 38 Further melting of the ice on the north beach. 24 January 1973. Photo by RWJ.

Fig. 39 New ice deposited at the north beach during the night of 24-25 January. New icefoot formation begun. 25 January 1973. Photo by Camera Monitor (CM).

Fig. 40 South beach during the January thaw. Beach ice has melted; the first lagoon is partially thawed; and large remnants of ridge C remain. New slush ice on the ridge face shows at the right. 25 January 1973. Photo by A-W.

Fig. 41 Condition of ice along the north beach. 26 January 1973. Photo by CM.

Fig. 42 Melting of the new ice along the north beach. 27 January 1973. Photo by CM.

Fig. 43 Iceless condition of the north beach. 28 January 1973. Photo by CM.

Fig. 44 No ice on the north beach. 29 January 1973. Photo by CM.

Fig. 45 New ice deposited and icefoot formation begun. 30 January 1973. Photo by CM.

Fig. 46 The new ice melting and being pushed ashore. 31 January 1973. Photo by CM.

Fig. 47 The north beach early in the day. 1 February 1973.

Fig. 48 Cavity under the ice pushed ashore. 1 February 1973.

Fig. 49 The north beach, late afternoon. No evidence of ice remains, but an incomplete sand ridge lies in the water's edge. 1 February 1973.

Fig. 50 The beach south of the plant with a limited amount of ice remaining. 1 February 1973.

Fig. 51 Sand ridge at the water's edge and what appears to be a residuum of the first lagoon. 2 February 1973. Photo by RWJ.

Fig. 52 Iceless north beach. This condition was maintained until 9 February. 3 February 1973. Photo by CM.

Fig. 53 Light deposition of new ice along the north beach. 9 February 1973. Photo by CM.

Fig. 54 Icefoot formation rebegun. 10 February 1973. Photo by CM.

Fig. 55 Formation of a new icefoot on the south beach. 10 February 1973. Photo by A-W.

Fig. 56, 57, 58, and 59 Stages in the progressive melting of the new ice on the north beach. 11 through 14 February 1973. Photos by CM.

Fig. 60 Iceless beach north of the plant. 15 February 1973.

Fig. 61 Iceless beach south of the plant. 15 February 1973.

Fig. 62 New ice accumulation late in the day. 15 February 1973. This condition of ice was maintained until 20 February. Photo by CM.

Fig. 63 Arrival of new sandy slush ice. 20 February 1973. Photo by CM.

Fig. 64 Increased new sandy slush ice. 21 February 1973. Photo by CM.

Fig. 65 A push of pack ice has compacted and elevated the belt of sandy slush ice. This ice condition remained until 24 February. 22 February 1973. Photo by CM.

Fig. 66 The north beach on 22 February 1973. Large very sandy iceballs on the beach, fewer and smaller ones on the first lagoon, and ridge C in the background shows sandy ice.

Fig. 67 Ridge C with large blocks of sandy slush ice and with an overcovering of small pieces of sheet ice. This condition remained through 23 February. 22 February 1973.

Fig. 68 Melting of the offshore ice field. 24 February 1973. Photo by CM.

Fig. 69 The offshore ice field completely gone. 25 February 1973. Photo by CM. The ice remained in this condition until 1 March.

Fig. 70 Shore ice in front of the plant looking north. Icefoot, first lagoon, and ridge C. 26 February 1973. Photo by A-W.

Fig. 71 Icefoot, first lagoon, and ridge C south of the plant. 26 February 1973. Photo by A-W.

Fig. 72 Ice at the Cook Plant. 27 February 1973.

Fig. 73 Beginning of melting. The belt of sandy ice is still visible down the high part of the ice of ridge C. 1 March 1973. Photo by CM.

Fig. 74, 75, 76, 77, 78, and 79 Progressive stages in the melting of the last shore ice at Cook Plant. 2 through 7 March 1973. Photos by CM.

Fig. 80 Meltoff completed. 8 March 1973. Photo by CM.

D. THE EFFECTS OF EXISTING THERMAL DISCHARGES ON LOCAL ICE BARRIERS

Investigations in this subject area were by foot surveys of Palisades and Campbell Stations on 11 January and by overflights on 27 February and 9 March. On 11 January the discharge plumes at both Palisades and Campbell were completely surrounded by the shore ice complex. Figures 1 through 8 are a north to south panorama of the plume at Palisades. In Figure 1 the B ridge of the shore icefoot shows in the center just to the left of the fence, and elevated parts of the outer D ridge show against the belt of sunlight in the background. In Figure 8 the sectioned B ridge south of the plume shows at the left. On this day Palisades was generating 600 Mwe with cooling water pumpage of 390,000 gallons per minute and a delta-T of 18 to 21°F.

Figures 9 through 12 are a north to south panorama of the Campbell Plant plume on 11 January. Plant operating data for Campbell Plant on 11 January were: pumpage 60,000 gpm through unit #1 and 90,000 gpm through unit #2; delta-T's were: unit #1 24°F and unit #2 25°F; and generation was 250 Mwe from unit #1 and 318 Mwe from unit #2.

On 27 February Palisades (Fig. 13) was down for repairs with no generation and a pumpage of 203,000 gpm of cooling water at 35°F. The breach through the outer ridge and the melted spot in the second lagoon are not related to plant operation. Figure 14 shows a similar breach and melted spot in the distance well away from the plant.

Figure 15 shows conditions at the Campbell Plant outfall on 27 February. The plume had melted completely through the shore ice complex for a short distance on either side of the outfall channel and was passing directly offshore with wisps of steam rising from the surface. Heavy erosion of the bluffs behind the ice in the foreground resulted from fall storms and high lake

level. Campbell Plant on this day was generating 560 net Mwe with a discharge flow of 150,000 gpm and a delta-T of 21°F.

Figure 16 shows ice conditions at Cook Plant on 27 February. The plant was not operating.

At the Michigan City Plant of Northern Indiana Public Service Company (Fig. 17) there was ice on shore on both sides of the outfall but the shore ice complex was completely melted. On this day, Michigan City was generating 113 Mwe with a cooling water flow of 82,000 gpm and a delta-T of 15°F.

At Bailly Station of NIPSCO on 27 February (Fig. 18) there was shore ice on both sides of the discharge flume though some melting by the plume was evident to the left (east) of the flume. A large block of the offshore D ridge lay directly in front of the discharge flume. Bailly on this day was generating 162 Mwe with a cooling water flow of 70,500 gpm and a delta-T of 9°F.

On 9 March (Fig. 19) the spring meltoff had removed the ice from the right (west) side of Bailly's discharge flume but very sandy residual shore ice was present along the beach to the left (east) of the flume. Bailly's operating data for this day were: 408 Mwe generated, cooling water flow of 153,880 gpm, and delta-T of 21°F.

Michigan City, Cook, Campbell, and Palisades were completely iceless on 9 March.

Extensive shore erosion along the southern and eastern shores of Lake Michigan took place from high water and fall storms of 1972, and more resulted from storms during the extended January thaw of 1973 which removed almost all the shore ice.

We have found no evidence that existing thermal discharges have promoted shore erosion by melting of local shore ice barriers.

FIGURE CAPTIONS

Fig. 1, 2, 3, 4, 5, 6, 7, and 8 — A panorama, from north through west around to south, of the melt spot of the plume at Palisades Nuclear Station. Ice completely surrounds the melt spot. See text for plant operating data for the day. 11 January 1973.

Fig. 9, 10, 11, and 12 — A panorama, north through west to south, of the melt spot of the plume of Campbell Station at Port Sheldon, Michigan. Ice completely surrounds the melted spot. See text for plant operating data of the day. 11 January 1973.

Fig. 13 — The plume at Palisades Station. The station was shut down for repairs at the time. 27 February 1973.

Fig. 14 — View northward at Palisades. The breach through the outer ridge, and open area in the second lagoon, are not related to the plant operations. Note a similar breach in the distance. 27 February 1973.

Fig. 15 — The plume area at Campbell Station. Steam wisps rising from the warm water of the discharge. 27 February 1973.

Fig. 16 — Ice conditions at the Cook Plant. 27 February 1973.

Fig. 17 — The Michigan City generating station. Ice on the shore on both sides of the outfall. 27 February 1973.

Fig. 18 — The outfall and intake of Bailly Station at Burns Harbor. Shore ice on both sides of the outfall flume and a large remnant of the outer ridge. 27 February 1973.

Fig. 19 — The Bailly Station outfall on 9 March 1973. Shore ice remains at the left of the flume, but spring meltoff has bared the beach at right.